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ABSTRACT

This glossary presents a standardized nomenclature for numerical control. It defines and describes some 286 technical words, terms, abbreviations, and acronyms which form a specialized vocabulary. The aim of this glossary is to provide a means for arriving at some common understanding of terminology for numerical control technology. Numerous entries in this glossary are used in metalworking, data processing, and other associated occupations. However, all the technical words, terms, abbreviations, and acronyms are defined and described as they apply to numerical control. A selected bibliography and an introduction which defines numerical control are also included. (HM)

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A VOCABULARY FOR NUMERICAL CONTROL

by

Clifton Paul Campbell

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PREFACE

This glossary presents a standardized nomenclature for numerical control. It defines and describes some 286 technical words, terms, abbreviations, and acronyms which form a specialized vocabulary. These words, terms, abbreviations, and acronyms were gathered from many sources and carry connotations not commonly found in ordinary reference dictionaries.

Numerous entries in this glossary are used in metalworking, data processing, and other associated occupations. Some find their roots in the "slang of the trade" and others have become accepted through repeated usage. Many are so new that they have seldom been indexed before. However, all these technical words, terms, abbreviations and acronyms are defined and described as they apply to numerical control. Whenever appropriate, definitions and descriptions provided by generally recognized sources were used to minimize proliferation and duplication.

The aim of this glossary is to provide a source for arriving at some common understanding of terminology which will facilitate more exacting communication. It should, therefore, be useful in minimizing misunderstandings and needless debates over problems of semantics. This glossary has been prepared for those who are conversant with numerically controlled equipment as well as those who seek a general understanding of numerical control technology.

Clifton Paul Campbell

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INTRODUCTION

Numerical control (N/C) is a technique for automatically controlling equipment. It is a system in which machine actions are determined by symbolic data recorded on a suitable media.

Acceptance and utilization of N/C equipment by industry is a fairly recent development. However, operational devices for drafting, industrial production, inspection and testing, and other manufacturing operations are becomingly increasingly more prevalent.

The direct control of the entire manufacturing enterprise from idea to finished product by externally prepared stored intelligence is possible. With N/C or automatic machines under tape command, we are in the fascinating era of direct communication with machines.

A designer is now able to sketch a part on the screen of a cathode ray tube with a light pen. On command a computer will refine the sketch into an engineering drawing, fully dimensioned - after having performed a complete range of analyses. Based on this drawing, the designer can modify the original concept and call for the computer's analytical procedure until satisfied. From this process, different types of input media can be produced which control machines that manufacture and inspect a workpiece. Numerical control, therefore, creates an interdependency of all the steps in the manufacturing sequence, from part conceptualization through the process that yields a finished product.

Since its commercial introduction in 1955, applied research and development have continued to advance numerical control technology. In particular, the reliability of control components has increased. Special systems for a variety of machine applications have been devised. A wide range of competing systems featuring varying combinations of electronic, electrical, hydraulic, optical, pneumatic, and mechanical control devices have become available.

Such refinements in hardware and their integration with the computer have altered many basic concepts of manufacturing. In terms of added capabilities and productivity, N/C is making a significant impact on the industrial community and its workforce.

ABSOLUTE ACCURACY.
Accuracy as measured from a reference which must be specified.

ABSOLUTE DIMENSION.
(See Coordinate dimension word). A dimension expressed with respect to the initial zero point of a coordinate axis.

ACCURACY.
(See Precision and Reproducibility). Conformity of an indicated value to the true value, i.e., an actual or an accepted standard value. (ASA C85) Measuring accuracy, precision, or reproducibility: Accuracy, precision, or reproducibility of position sensor or transducer and interpreting system. Control positioning accuracy, precision, or reproducibility: Accuracy, precision, or reproducibility of position sensor or transducer and interpreting system and including the machine positioning servo. (May be the same as machine positioning accuracy, precision, or reproducibility in some systems.) Machine positioning accuracy, precision, or reproducibility: Accuracy, precision, or reproducibility of position sensor or transducer and interpreting system, the machine elements and the machine positioning servo. Cutter, spindle and work deflection and cutter wear are not included. (May be the same as control positioning accuracy, precision, or reproducibility in some systems.) Machining accuracy, precision, or reproducibility: Accuracy, precision, or reproducibility obtainable on completed parts under normal operating conditions.

ADAPT.
Air Material Command Developed APT. A three-axis continuous path program written by IBM under contract with the U. S. Air Force. A general processing type of program written for small to medium sized computer whose rental would be $3,000 - $7,000 per month, and whose add time would be in the order of 600 microseconds.

ADAPTIVE CONTROL.
Descriptive of systems which represent an extension of closed loop, feedback control, in that performance of the machine, process, or other controlled object is optimized, rather than merely corrected. At present state of development, most adaptive machine-tool controls are special-purpose systems which sense tool torque and optimize feed-rates and speeds for small-hole drilling of extremely hard substances. Synonymous with self-optimizing control.

ADDRESS.
Means of identifying information or a location in a control system. Example: The "X" command in the command X 12345 is an address identifying the numbers 12345 as referring to a position on the X axis.

AEROSPACE INDUSTRIES ASSOCIATION OF AMERICA, INC. (AIA).
The national trade association of the manufacturers of aircraft, missiles, spacecraft propulsion, navigation and guidance systems, support equipment, accessories parts, and materials and components used in the construction, operation, and maintenance of these products.

ALPHANUMERIC CODING.
A code system in which the characters used are the letters of the alphabet and the numerals 0 to 9.

AMPLIFIER.
A device for increasing the voltage, current, or power level of an electrical signal. In a N/C system, it is normally the part of the servo-system which amplifies the error signal and provides the power to drive the machine slides or the

servo-valve controlling a hydraulic drive.

ANALOG.
Denotes the use of physical variables, e.g., distance, rotation, or voltage, to represent and correspond with numerical variables that occur in a computation (as opposed to digital).

ANALOG AND DIGITAL DATA.
Analog data implies continuity as contrasted to digital data which is concerned with discrete states. Many signals can be used in either the analog or digital sense, the means of carrying the information being the distinguishing feature. The information content of an analog signal is conveyed by the value or magnitude of some characteristics of the signal such as the amplitude, phase or frequency of a voltage, the amplitude or duration of a pulse, the angular position of a shaft, or the pressure of the fluid. To extract the information, it is necessary to compare the value or magnitude of the signal to a standard. The information content of a digital signal is concerned with discrete states of the signal, such as the presence or absence of a voltage, a contact in the open or closed position, or a hole or no hole in certain positions on a card. The signal is given meaning by assigning numerical values or other information to the various possible combinations of the discrete states of the signal.

AND CIRCUIT.
A circuit which produces an output only when all requisite input signals are present. Also called a "gate."

APT.
An abbreviation of Automatic Programmed Tools. APT is a computer-based Numerical Control programming system which uses English-like symbolic descriptions of part and tool geometry, and tool motion.

ASA.
American Standards Association.

ASCII.
American Standard Code for Information Interchange.

ASSEMBLE.
To integrate subroutines into the main routine by adapting or changing relative and symbolic addresses to absolute form.

AUTOMAP.
AUTOmatic MAchining Program. A computer language by which an object can be described from an engineering drawing. The general descriptive statements are translated by the AUTOMAP program into detailed instructions required to direct the action of the machine tools. Two-dimensional limitation, and proprietary with IBM.

AUTOMATIC DRAFTING MACHINE.
A sophisticated X-Y plotter, usually used in conjunction with a computer, which produces graphic output from numerical input. Frequently capable of printing letters, numbers, and symbols as well as drawing and scribing lines and curves. Useful in areas such as design analysis, engineering mechanical drawing preparation, and cutter center-path verification for numerical machining. Contrasted with digitizing machine.

AUTOMATIC PROGRAMMING.
A term for all techniques which are designed to simplify the writing and execution of programs. Assembly programs which usually translate from the programmer's symbolic language, assign absolute address to instruction and data words, and integrate subroutines into the main routine, are examples of automatic programming aids.

AUTOMATION.
The investigation, design, development, and application of methods of rendering processes self-controlling through feedback analysis.

AUTOPROMT.
AUTOmatic PROgraMmed Tools. An IBM developed contouring program for the 7090 computer. Uses different language than APT. Unlike APT, AUTOPROMT is available internationally through IBM service centers.

AUTOPROPS.
AUTOmatic PROgram for Positioning System. A two-axis, point-to-point program developed jointly by IBM and Pratt and Whitney for the IBM 1401 computer.

AUTOSPOT.
AUTOmatic System for POsitioning Tools. A general-purpose computer program designed to aid the parts programmer prepare instructions for numerically controlled machine tools. Point-to-point capability only. Proprietary with IBM.

AUXILIARY FUNCTION.
A function of a machine other than the control of the coordinates of a workpiece or tool. Includes functions such as miscellaneous, feed, speed, tool selection, etc. Not a preparatory function.

AUXILIARY FUNCTION WORD.
A word used to command auxiliary actions such as coolant on or off.

AXIS.
(1) One of the lines of direction or motion on a machine.
(2) One of the reference lines of a coordinate system.

BACKLASH (ASA C85).
A relative movement between interacting mechanical parts, resulting from looseness.

BASE-LINE DIMENSIONING.
Descriptive of designing and part drawing technique of recording dimensions as distances from a base line, which may be outside the part, in order to reduce duplication of effort and simplify mathematical tasks of numerical control part programmers.

BATCH PROCESSING.
A method of processing jobs on a computer where they are organized and handled one at a time. The opposite of "time sharing" where one has immediate access to a computer.

BED.
Fixed portion of machine structure which may provide a work mounting surface and will support other machine elements (table, ways, column, saddle, gantry, etc.).

BERT.
Basic Electronic Resolution Technique. The manufacturer's software programming package which will eliminate the requirement for customer programming.

BIAS.
The average d.c. voltage maintained between the cathode and control grid of a vacuum tube.

BINARY CODE.
A code in which each allowable position has one of two possible states. A common symbolism for binary states is 0 and 1. The binary number system is one of many binary codes.

BINARY-CODED-DECIMAL SYSTEM (BCD).
A system of number representation in which each decimal digit is represented by a group of binary digits forming a character.

BINARY DIGIT.
A digit in the binary scale of notation. This digit may be only 0 (zero) or 1 (one). It is equivalent to an "on" condition or an "off" condition, a "yes" or a "no," etc.

BINARY NOTATION.
The writing of numbers in the scale of two. The first dozen numbers zero to eleven are written 0, 1, 10, 11, 100, 101, 110, 111, 1000, 1001, 1010, 1011. The position of the digits designate powers of two; thus 1010 means 1 times two cubed or eight, 0 times two squared or 4, 1 times two to the first power or two, and 0 times two to the zero power or one; this is equal to one eight plus no four's plus one two plus no one's, which is ten.

BIT.
(1) An abbreviation of "binary digit." (2) A single character of a language employing exactly two distinct kinds of characters.

BLOCK.
A word or group of words considered as a unit and separated from other such units by an End of Block character.

BLOCK ADDRESS FORMAT.
Means of identifying words by use of an address specifying the format and meaning of the words in a block.

BLOCK DELETE.
This feature provides a means for skipping certain blocks by programming a slash (/) code ahead of the block. The feature is useful when the operator desires to leave off certain cuts on a particular part configuration.

BLOCK READER.
A tape reader which will read a complete block of information at the same time.

BOOLEAN ALGEBRA.
A process of reasoning, using a symbolic logic, and dealing with on-off circuit elements. It employs symbols to represent AND, OR, NOT EXCEPT, IF . . . THEN, etc., to permit mathematical calculation. Named after George Boole, famous English mathematician (1815-1864).

BUFFER STORAGE.
An intermediate storage medium between data input and active storage.

BUG.
An error or flaw in a program that renders it incapable of performing the objectives for which it was written.

BYTE.
A sequence of binary digits usually operated upon as a unit.

CAMP I.
Compiler for Automatic Machine Programming. A 3-axis point-to-point program written by Westinghouse Electric Corporation for the LGP-30 computer made by General Precision, Inc. It was written specifically for the Milwaukee-Matic.

CAMP II.
Compiler for Automatic Machine Programming. A 2-5 axis point-to-point program written cooperatively by Westinghouse and IBM for the IBM 7090 and IBM 7094 computers. Consists of 120 command variables for automatic machine programming.

CANCEL.
A command which will discontinue any fixed cycles or sequence commands.

CARD-TO-TAPE CONVERTER.
A device which converts information directly from punched cards to punched or magnetic tape.

CARTESIAN COORDINATE.
(1) The distance of a point from either of two intersecting straight-line axes measured parallel to the other axis.
(2) The distance from any of three intersecting coordinate planes measured parallel to that one of three straight-line axes that is the intersection of the other two planes.

CASCADE CONTROL.
An automatic control system in which the control units, linked in chain fashion, feed into one another in succession, each regulating the operation of the next line. Sometimes called "piggy back" control.

CHAD.
The pieces of material that are removed when punching holes in tape or cards.

CHARACTER.
One of a set of elementary marks or events which may be combined to express information. Example: The characters normally used in numerical control include those representing the decimal digits 0 to 9, the letters of the alphabet, and special characters such as Tab, End of Block, and End of Record.

CHIPMAKING.
The cutting away of excess metal, in the form of chips, from a workpiece by use of a cutting tool. Differentiated from abrading or grinding because of the larger sizes of chips removed and by higher metal-removal rates.

CIRCULAR INTERPOLATION.
A mode of contouring control which uses the information contained in a single block to produce an arc of a circle. The velocities of the axes used to generate this arc are varied by the control.

CLOCK.
A source of accurately timed pulses for a numerical control unit. They are used to form signals corresponding to data that is to be processed.

CLOCK RATE.
The rate at which clock pulses are generated. The rate is expressed in units of hertz.

CLOSED LOOP SYSTEM.
A system in which the output, or some result of the output, is fed back for comparison with the input, for the purpose of reducing the difference.

CODE.
A system of signals or characters and rules for their interpretation. For punched or magnetic tape, a predetermined arrangement of possible locations of holes or magnetized areas and rules for interpreting the various possible patterns.

CODED-DECIMAL CODE.
The decimal number system with each decimal digit expressed by a code.

COLLATOR.
A device for determining the coincidence or noncoincidence of two signals, and signaling the results of the comparison.

COMMAND.
(1) An electronic pulse, signals, or set of signals to start, stop, or continue some operation. It is incorrect to use command as a synonym for instruction. (2) That portion of an instruction word which specifies the operation to be performed.

COMPARATOR CIRCUIT.
A circuit which compares two signals and supplies an indication of agreement or disagreement.

COMPATIBILITY.
The degree to which tapes, languages, and programming can be interchanged among various machine tools and N/C systems.

COMPILER.
A computer program more powerful than an assembler. In addition to its translating function, which is generally the same process as that used in an assembler, it is able to replace certain items of input with series of instructions, usually called subroutines. Thus, where an assembler translates item for item, and produces as output the same number of instructions or constants which were put into it, a compiler will do more than this. The program which results from compiling is a translated and expanded version of the original.

COMPUTER.
A device capable of accepting information, applying prescribed processes to the information, and supplying the results of these processes. It usually consists of input and output devices, storage, arithmetic, and logical units, and a control unit.

CONTINUOUS DATA.
Data of which the information content can be ascertained continuously in time.

CONTINUOUS PATH.
A type of N/C machine operation in which rate and direction of relative movement of machine members is under continuous control.

CONTOURING CONTROL SYSTEM.
A system in which the controlled path can result from the coordinated, simultaneous motion of two or more axes.

CONTROL CIRCUITS.
The circuits which effect the carrying out of instructions.

CONTROLLER.
An apparatus of unitized or sectional design, through which commands are introduced and manipulated. A program controller has the following functions; data, computation, encoding, storage, readout, process computation, and output.

CONVERSION OF EQUIPMENT.
To change or adapt a basic piece of machinery or equipment.

COORDINATE DIMENSION WORD.
A word defining an absolute dimension.

COORDINATES.
Positions or relationships of points or planes.

CORE MEMORY.
A programmable, random-access memory consisting of many ferromagnetic cores strung on wires in matrix arrays.

CUTTER COMPENSATION.
Displacement, normal to the cutter path, to adjust for the difference between actual and programmed cutter radii or diameters.

CYBERNETICS.
The field of technology involved in the comparative study of the control and intracommunication of information-handling machines and nervous systems of animals and man in order to understand and improve communication.

CYCLE.
A set of operations performed in predetermined manner.

DAMPING.
The reduction or suppression of oscillation in a system. Damping is critical when it is sufficient to prevent any overshoot of output due to an abrupt stimulus.

DATA.
Any facts or information particularly as taken in, operated on, or put out by a machine for handling information.

DATA HANDLING SYSTEM.
Automatic handling such as sorting, decoding or storing of information in desired form. Sometimes called data reduction system.

DATA LINK.
Equipment which permits the transmission of information in data format.

DATA PROCESSING.
The transition of numerically descriptive engineering and manufacturing data into a form suitable for machine control.

DATA REDUCTION.
Conversion of a large quantity of raw test information or experimentally obtained data into a small quantity of useful, summarizing information.

DEBUG.
(1) To locate and correct any errors in a computer program or part program. (2) To detect and correct malfunctions in a computer, control system, or machine.

DECADE.
A group or assembly of ten units; e.g., a counter which counts to ten in one column or a register box which inserts resistance quantities in multiples of powers of ten.

DECIMAL CODE.
A code in which each allowable position has one of 10 possible states. The conventional decimal number system is a decimal code.

DECIMAL DIGIT.
One of the symbols 0 through 9 when used in numbering in the scale of ten.

DECODING.
Translation from a coded form to an analog or other easily recognized form, without significant loss of information.

DIGIT.
A character in any numbering system.

DIGITAL.
Refers to discrete states of a signal (i.e., either on or off). Since a combination of on-off signals make up a specific value, the magnitude of each signal is irrelevant. The theoretical extent of accuracy of a digital system is therefore unlimited and will depend on the amount and cost of electronics involved. Numerical control systems may be of analog, digital, or combination analog-digital type of construction.

DIGITAL COMPUTER.
A computer which processes information represented by combinations of discrete or discontinuous data as compared with an analog computer for continuous data. More specifically, it is a device for performing sequences of arithmetic and logical operations, not only on data but its own program. Still more specifically, it is a stored program digital computer capable of performing sequences of internally stored instructions, as opposed to calculators, such as card programmed calculators, on which the sequence is impressed manually.

DIGITIZE.
The conversion of analog to digital data. (A/D).

DIGITIZING MACHINE.
A machine, similar in appearance to automatic drafting machine, which senses lines and curves on graphic input, such as an engineering mechanical drawing, and converts to numerical tape and/or printed output. May be operated by programming personnel who type auxiliary machine-tool commands for merger with geometric data such as cutter center-paths, to produce complete machine control tapes for numerical machining. May be automatic drafting machine with additional equipment which permits digitizing.

DISCRETE UNITS.
Distinct units; units of a digital nature, as opposed to a continuous information flow which is analog.

DOWNTIME.
The period during which a system, computer, or any other device is malfunctioning or not operating, due to electronic, mechanical, or other inherent failure.

DRUM MEMORY.
A memory consisting of a magnetizable coating on the outer surface of a rotating cylinder. Drums are typically non-programmable, bulk-storage, random-access memories.

DWELL.
A timed delay of programmed or established duration, not cyclic or sequential, i.e., not an interlock or hold.

DYNAMIC BEHAVIOR.
Describes how a control system or an individual unit performs with respect to time.

EIA STANDARD CODE.
A standard code for positioning, straight-cut and contouring control systems proposed by the U. S. Electronic Industries Association in their Standard RS-244. It uses eight-track paper tape, one inch wide, and is known as 8-B code. It has been recognized by the German V.D.I. and may possibly become a universal standard. It has recently been accepted by the American Standards Association as an American standard for numerical control.

ELECTRONIC DATA PROCESSING (EDP) SYSTEM.
The general term used to define a system for data processing by means of machines utilizing electronic circuitry at electronic speed, as opposed to electromechanical equipment.

ELECTRONIC INDUSTRIES ASSOCIATION (EIA).
A national trade association representing manufacturers of electronic parts, equipment, and systems for consumer, industrial, and military applications. The subject of numerical control is one of many within the electronics area.

ELECTRONIC SWITCH.
A circuit element causing a start and stop action or a switching action electronically, usually at high speed.

ENCODING.
Translation to a coded form from an analog or other easily recognized form, without significant loss of information.

END OF BLOCK SIGNAL.
A symbol or indicator that defines the end of one block of data.

END OF PROGRAM.
A miscellaneous function indicating completion of workpiece. Stops spindle, coolant, and feed after completion of all commands in the block. Used to reset control and/or machine. Resetting control may include rewind of tape or progressing a loop tape through the splicing leader. The choice for a particular case must be defined in the format classification sheet.

END OF TAPE.
A miscellaneous function which stops spindle, coolant, and feed after completion of all commands in the block. Used to reset control and/or machine. Resetting control will include rewinding of tape, progressing a loop tape through the splicing leader, or transferring to a second tape reader.

The choice for a particular case must be defined in the format classification sheet.

END-POINT CONTROL.
Quality control through continuous automatic analysis. The final product is analyzed and the process changed if there are undesirable variations.

EQUILIBRIUM.
A state of balance.

ERROR COUNTER or ERROR REGISTER.
This is a device for accumulating and signaling the algebraic difference between desired machine movement and the actual movement of the machine.

ERROR SIGNAL.
A signal inside a closed-loop system representing the difference between desired position and actual position.

EXTERNAL MEMORY.
A storage medium outside the system, such as a punched or a magnetic tape.

FEED FUNCTION.
The relative velocity between the tool or instrument and the work due to motion of the programmed axis (axes).

FEED RATE BY-PASS.
A function directing the control system to ignore programmed feed rate and substitute a selected operational rate.

FEED-RATE NUMBER.
A number read from the tape, governing the rate at which command pulses are emitted from the interpolator.

FEED RATE OVERRIDE.
A manual function directing the control system to modify the programmed feed rate by a selected multiplier.

FEEDBACK LOOP.
The part of a closed loop system which provides controlled response information allowing comparison with a referenced command.

FIELD.
A set of one or more characters (not necessarily all lying in the same word) which is treated as a unit of information.

FIXED BLOCK FORMAT.
A format in which the number and sequence of words and characters appearing in successive blocks is constant.

FIXED CYCLE or CANNED CYCLE.
A preset series of operations which direct machine axis movement and/or cause spindle operation to complete such action as boring, drilling, tapping, or combinations thereof.

FIXED SEQUENTIAL FORMAT.
Means of identifying a word by its location in the block. Words must be presented in a specific order and all possible words preceding the last desired word must be present in the block.

FIXED WORD-LENGTH.
Having the property that a machine word always contains the same number of characters or digits. Contrasted with variable word-length.

FLIP FLOP.
A circuit having two stable states, either of which may be induced by means of suitable input signals.

FLOATING ZERO (See ZERO OFFSET).
A characteristic of a numerical machine control permitting the zero reference point on an axis to be established readily at any point in the travel. The control retains no information on the location of any previously established zeros.

FORMAT.
A systematic arrangement of data. As applied to tape or cards, the rules defining the position of the bits. As applied to manuscripts, the rules defining the structure of the information.

FORMAT CLASSIFICATION.
A means, usually in an abbreviated notation, by which the motions, dimensional data, type of control system, number of digits, auxiliary functions, etc. for a particular system can be denoted.

FORMAT DETAIL.
Describes specifically which words and of what length are used by a specific system in the format classification.

FORTRAN.
Acronym for FORmula TRANslation, a universal computing language in which many N/C master programs are written.

FREQUENCY RESPONSE.
A measure of the ability of a device, or a system, to follow or act upon a rapidly varying input condition.

G FUNCTION.
A preparatory code on a program tape to indicate a special function. The "g" is actually a lower case letter when shown on a printout. For example: g90 indicates that all following coordinate locations are expressed in absolute dimensions and g91 indicates they will be expressed incrementally. Of course such functions would only be utilized on machine control units having the capabilities called for by the function.

GATE.
A circuit which yields an output signal that is dependent on some function of its present or past input signals.

GECENT.
A general postprocessor written in modular form for the General Electric Century Control Systems. It is written for the additional capabilities of APT III. The program is almost entirely written in FORTRAN, the universal compiler language.

GENERAL PROCESSOR.
Also referred to as master programs. This is the program containing the basic intelligence for N/C work that is stored in computer memory before individual workpiece programs can be processed. APT and ADAPT are general processors and many machine tool builders, machine control unit manufacturers

and service organizations have prepared and make available general processors.

GRAPHIC PANEL.
A master control panel which, pictorially and usually colorfully, traces the relationship of control equipment and the process operation. It permits an operator at a glance, to check on the operation of a far flung control system by noting dials, valves, scales, and lights.

GRATING.
Gratings provide a method of measuring from one point to another. The movement between a pickup cell and an optical grating produce variations in the intensity of light on a multiple photosensitive device. These are converted into electrical pulses which are counted and fed back as data into the basic control system. The ambiguity between the counts produced and the counts commanded can be diminished to zero as a slide is positioned to its predetermined point.

HARD COPY.
Any form of computer-produced document. Also, punched cards or paper tape.

HARDWARE.
The physical component parts of a machine control unit or computer. See also Software.

HEAD.
A device which reads, records, or erases information in a storage medium--usually a small electro-magnet used to read, write or erase information on a magnetic drum or tape, or the set of perforating or reading fingers and block assembly for punching or reading holes in paper tape or cards.

HERTZ.
Accepted term for cycle-per-second.

HOLD.
An untimed delay in the program, terminated by an operator or interlock action.

HOLOGRAPHY.
Descriptive of types of photography or wavefront reconstruction, not employing lenses, in which interference patterns rather than conventional images are recorded, and in which a coherent light source is used to reconstruct data from photographic, radar, or other acquisition systems in apparent three-dimensional form.

HUNTING.
A continuous attempt, on the part of an automatically controlled system, to seek a desired equilibrium condition.

INCREMENT.
The value which is added to a coordinate dimension to produce a change.

INCREMENTAL DIMENSION or DELTA DIMENSION.
A dimension expressed with respect to the preceding point in a sequence of points.

INCREMENTAL FEED.
A manual or automatic input of preset motion command for a machine axis.

INDUCTOSYN.
Trade name for linear and rotary feedback devices manufactured by Farrand Controls, Inc.

INFORMATION THEORY.
The mathematical theory concerned with information rate, channels, channel width, noise, and other factors affecting transmission. Initially developed for electrical communications, it is now applied to business systems, and other phenomena which deal with information units and flow of information in networks.

INPUT.
Transfer of external information into the control system.

INPUT EQUIPMENT.
The device which takes outside information into a machine.

INSTRUCTION STORAGE.
Storage media containing basic machining instructions in coded form.

INSTRUMENTATION.
The application of a measuring device to a process.

INTEGRATED CIRCUITS.
Also known as IC's. A very small single structure assembly of electronic components containing many circuits and functions. Modern computers and machine control units are made with IC's instead of transistors or vacuum tubes.

INTELLECTRONICS.
Communication between man and electronic machines on intellectual activities. Requisities: Worldwide common, logical language - color codes, sound patterns, finger snaps or taps, or the replacement of the decimal system by the binary ("2" as a base) or octal ("8" as a base) numbering system.

INTERFACE.
The medium by which two separate elements are joined. There is an interface between machine control unit and machine tool comprised of electrical circuitry and drive motors. If a computer directly controls a machine tool there is an appropriate interface.

INTERLOCK BY-PASS.
A command to temporarily circumvent a normally provided interlock.

INTERPOLATOR.
A device for defining the path to be followed, and the rate of travel of a cutting tool or of a machine-tool slide or element, when supplied with a coded mathematical description of the same. It provides the link between programmed points and smooth curves.

LAG.
A relative measure of the time delay between two events, states, or mechanisms.

LANGUAGE.
The association or rule which is used to represent code information.

LEAD SCREW.
An extremely accurate threaded shaft used to convert rotation to longitudinal motion.

LEADER.
The section of tape which appears ahead of and after a section of coded tape. When producing leader by punching tape feed, sprocket holes are produced. It may also include a parity code.

LINEAR INTERPOLATION.
A mode of contouring control which uses the information contained in a block to produce velocities proportioned to the distance moved in two or more axes simultaneously.

LOGIC.
(1) The systematic scheme which defines the interactions of signals in the design of an automatic data processing system. (2) The basic principles and application of truth tables and inter-connection between logical elements required for arithmetic computation in an automatic data processing system.

M FUNCTION.
Similar to a "g" function except that the "m" functions control miscellaneous functions of the machine tool such as turning on and off coolant or operating power clamps and so on.

MACHINE ACTUATOR or MACHINE SERVOMOTOR.
A power device for directly effecting machine motion.

MACHINE CONTROL UNIT (MCU).
Synonymous with numerical control system in its hardware form. Sometimes referred to as the "director" or "controller."

MAGNETIC TAPE.
A tape or ribbon of any material impregnated or coated with magnetic or other material on which information may be placed in the form of magnetically polarized spots.

MANUAL DATA INPUT.
A means for the manual insertion of numerical control commands.

MANUAL MODE.
A method of operation where data is entered manually by dial or other means instead of by program tape. A machine may be entirely program controlled, it may have certain functions which are done manually or in some instances it may be entirely under manual operation.

MANUSCRIPT (See PROGRAMMING).
An ordered list of numerical control instructions.

MATRIX.
An orderly array of devices, numbers, or units.

MIRROR IMAGE PROGRAMMING.
A feature of some machine control units that provides for the reversing of all instructions programmed for a specific axis (usually X) by means of a switch. This means that a single program tape can produce two mirror image parts.

MIXED SEQUENTIAL FORMAT.
A format in which a word is identified by its location in the block. Words must be presented in a specific order, and all possible words preceding the last desired word must be present in the block.

MNEMONIC CODE.
Instructions which are in written form for ease of handling but which later must be converted into machine language.

MODULE.
(1) An interchangeable plug-in item containing components.
(2) An incremental block of storage, or other building-block, for expanding the computer capacity.

MYLAR.
Trademark of DuPont for their polyester film that is widely used for insulating purposes and as a backing for tape.

NATIONAL AEROSPACE STANDARDS (NAS).
A series of AIA-developed standards covering such aerospace hardware as fasteners, fittings, and electrical items; specifications for aerospace materials, packaging materials, and machine tools; and testing procedures. Approximately one hundred standards were issued or revised in 1966. The year 1967 marked its twenty-fifth anniversary.

NCMT.
Numerically Controlled Machine Tool(s).

NMTBA.
National Machine Tool Builders Association.

NOISE.
A term used to describe stray electrical impulses that can disturb the normal operation of a machine control unit or computer.

NOR CIRCUIT.
A circuit which will not produce an output signal when any of its input signals are present. Inverse of AND circuit.

NUMBER SYSTEMS.
Position notation. A systematic method for expressing numerical data.

NUMERICAL CONTROL SYSTEM.
A system in which actions are controlled by the direct insertion of numerical data at some point. The system must automatically interpret at least some portion of this data.

NUMERICAL DATA.
Data in which information is expressed by a set of numbers or symbols that can only assume discrete values or configurations.

OFF-LINE OPERATION.
Usually applies to peripheral equipment which operates independently of the central computer. This equipment is generally utilized where it is not necessary to operate the full capabilities of the major portion of the computer, thus saving time and expense.

ON-LINE OPERATION.
Applies to computer operations and calculations which are performed by the computer itself or the major portion of the computer.

OPEN LOOP SYSTEM.
A control system that has no means for comparing the output with input for control purposes.

OPERATION NUMBER.
A number indicating the position of an operation in performance sequence.

OPTIMIZATION.
A method by which a process is continually adjusted to the best obtainable set of operating conditions.

OPTIONAL STOP or PLANNED STOP.
A miscellaneous function command similar to a program stop except that the control ignores the command unless the operator has previously pushed a button to validate the command.

OR CIRCUIT.
A circuit which provides an output when any of its input signals are present.

OVERSHOOT.
Occurs when results exceed the target value.

PAPER TAPE.
A strip of paper capable of storing or recording information. Storage may be in the form of punched holes, partially punched holes, carbonization or chemical change of impregnated material, or by imprinting. Some paper tapes, such as punched paper tape, are capable of being read by the input device of a computer or a transmitting device by sensing the pattern of holes which represent coded information.

PARABOLIC INTERPOLATION.
A high order of interpolation producing contoured shapes by having the cutting tool travel through parabolas or portions of parabolas. This method of interpolation is particularly applicable to mold or die work where free form shapes can be generated with a minimum number of program steps.

PARALLEL ENTRY.
All characters displayed simultaneously as opposed to serial.

PARITY CHECK.
A means of determining whether a character has an odd or an even set of marks to describe it. Usually characters in a code are all odd or even. An extra "parity mark" is added to make this the case.

PART PROGRAMMING, COMPUTER.
The preparation of a manuscript in computer language and format required to accomplish a given task. The necessary calculations are to be performed by the computer.

PART PROGRAMMING, MANUAL.
The preparation of a manuscript in machine control language and format required to accomplish a given task. The necessary calculations are to be performed manually.

PATCH.
A section of coding inserted into a routine to correct a mistake or alter the routine.

PATH STORAGE.
Storage media containing interpolated path of tool and instructions for auxiliary functions.

PERFORATED TAPE.
Tape in which a code hole(s) and a tape feed hole have been punched in a row.

PERIPHERAL EQUIPMENT.
The auxiliary machines which may be placed under the control of the central computer. Examples of this are card readers, card punches, magnetic tape feeds, and high-speed printers. Peripheral equipment may be used on-line or off-line depending upon computer design, job requirements, and economics.

POLAR COORDINATE.
Either of two numbers that locate a point in a plane by its distance from a fixed point on a line and the angle this line makes with a fixed line.

PORTABLE STORAGE.
A storage medium that can be easily transported without loss of stored data.

POSITION SENSOR or POSITION TRANSDUCER.
A device for measuring a position, and converting this measurement into a form convenient for transmission.

POSITION STORAGE.
Storage media containing major positions of tool and instructions for auxiliary functions.

POSITIONING CONTROL SYSTEM or POINT-TO-POINT CONTROL SYSTEM.
A system in which the controlled motion is required only to reach a given end point, with no path control during the transition from one end point to the next.

POST PROCESSOR.
A set of computer instructions which transform tool centerline data into machine motion commands using the proper tape code and format required by a specific machine/control system. Instructions such as feedrate calculations, spindle speed calculations, and auxiliary function commands may be included.

PRECISION (ASA C85) (See ACCURACY and REPRODUCIBILITY).
Closeness of agreement among repeated measurements of the same characteristic by the same method under the same conditions.

PREPARATORY FUNCTION.
A command changing the mode of operation of the control such as from positioning to contouring or calling for a fixed cycle of the machine.

PRINTER.
An output mechanism which prints or typewrites characters.

PRINTOUT.
A printed sheet giving all the data of a program that has either been manually or computer processed. The printout is used for reference and visual checking. Normally the printout will be made at the same time a tape is punched.

PROCESS CONTROL.
Descriptive of systems in which digital, analog or hybrid computers are used for the automatic regulation of operations or processes. Typical are operations in the production of chemicals wherein the operation control is applied continuously and adjustments to regulate the operation are directed by the computer to keep the value of a controlled variable constant.

PROGRAM STOP.
A miscellaneous function command to stop the spindle, coolant and feed after completion of other commands in the block. It is necessary for the operator to push a button in order to continue with the remainder of the program.

PROGRAMMER (COMPUTER PROGRAMMER).
A person who prepares computer programs which are to be used internally in the computer in order to solve the specific problems presented by the part programmer. A numerical control computer programmer generally requires a formal advanced mathematical background in addition to a thorough knowledge of computer operations.

PROGRAMMER (PART PROGRAMMER).
A person who prepares the planned sequence of events for the operation of a numerically controlled machine tool. The programmer's principal tool is the manuscript on which the instructions are recorded.

PROGRAMMING.
The ordered listing of a sequence of events designed to accomplish a given task.

PRONTO.
PROgram for Numerical TOols. A 3-axis point-to-point program, developed by General Electric. Uses a three-to-six letter mneumonic vocabulary of approximately 50 words. Applies to IBM 704 and GE 225 computers.

PROTOTYPE.
A first, or original, model which, after testing and refining, is the basis for the final product.

PULSE.
A pattern of variation of a quantity, such as voltage or current, consisting of an abrupt change from one level to another, followed by an abrupt change to the original level.

PUNCH CARD.
A card of constant size and shape, suitable for punching in a pattern that has meaning, and for being handled mechanically. The punched holes are usually sensed electrically by wire brushes or mechanically by fingers.

PUNCHED TAPE.
Paper tape punched in a pattern of holes so as to convey information.

QUANTUM.
The numerical value of the smallest unit of measure used in a system.

RADIX.
Base or root. A number that is arbitrarily made the fundamental number of a number system. The quantity of different symbols required to express any integer in a number system.

RANDOM ACCESS.
Indicates equality of access time to all memory locations, without dependence on the location of the previous memory reference.

RAW STORAGE.
Storage media, such as drawings, containing all information (geometry of part, cutter size, feeds and speeds, etc.) necessary for preparation of the manuscript.

READ.
To sense the characters numerical input information such as performed by input equipment.

READOUT, COMMAND.
Display of absolute position as derived from position command.

READOUT, POSITION.
Display of absolute position as derived from a position transducer.

REAL TIME.
The ability of a computer to function and control a process as that process occurs. For example: a computer directly controlling the operation of a machine tool would be a real time application. If a computer generates a program tape and the tape is utilized at some later time, the computer has been used in an "off-line" application.

RECIRCULATE.
To transfer information from the output to the input without shifting the order of sequence.

REFERENCE BLOCK.
A block within the program identified by an "o" (letter o) in place of the word address "n" and containing sufficient data to enable resumption of the program following an interruption. This block should be located at a convenient point in the program which enables the operator to reset and resume operation.

REPRODUCIBILITY (ASA C85) (See PRECISION and ACCURACY).
The ability of a system or element to maintain its output/input precision over a relatively long period of time.

RESOLUTION (ASA C85).
The least interval between two adjacent discrete details which can be distinguished one from the other.

RETROFIT.
To take a conventional machine tool and to outfit it with numerical controls. It is not an original designed NCMT and performs as a retrofit. Most retrofits do not reach the peaks of efficiency as a true designed-from-scratch NCMT.

ROUTINE.
A set of coded instructions, supplied to a general purpose computer, which established a sequence of operations to be followed in the logical processing of a class of data.

ROW.
A path perpendicular to the edge of a tape along which information may be stored by presence or absence of holes or magnetized areas.

SAMPLED DATA.
Data in which the information content can be, or is, ascertained only at discrete intervals of time. Sampled data may be analog or digital.

SCANNER.
An instrument which checks a number of measuring points in some sequence.

SEGMENT.
That portion of a path joining two successive points stored in position storage medium.

SENSITIVITY.
The ability of a device or system to respond to its smallest command.

SEQUENCE NUMBER.
A number identifying the relative location of blocks or groups of blocks on a tape.

SEQUENCE NUMBER READOUT.
Display of the sequence number punched on the tape.

SEQUENTIAL.
Arranged in some predetermined logical order.

SERIAL OPERATION.
Type of information transfer within a digital computer whereby all digits of a word are handled sequentially rather than simultaneously.

SERVOMECHANISM (ASA C85).
An automatic feedback control system in which the controlled variable is mechanical position or any of its time derivatives.

SIGN DIGIT.
A plus or a minus to designate the positive or negative characteristic of a coordinate.

SKIP.
An instruction to proceed to the next instruction. See also Tab.

SNAP.
Simplified Numerical Automatic Programmer. A 2-axis point-to-point program written for the Brown & Sharpe Turr-E-Tape Drill and designed for the IBM 1401 data processing system.

SOFTWARE.
All of the program manuscripts, tapes, decks of tabulating cards, methods sheets, flow charts and other programming documentation associated with computers and N/C. Its counterpart is the physical hardware comprising the computer or N/C system.

SOLID STATE.
The logic of a computer or machine control unit made solely of solid-state electronic components. There are no relays, vacuum tubes and so on.

SPECIFIED CUTTING TOLERANCES.
Allowable deviations of measurement of a test part or parts from the programmed dimension, which may result from control error, machine deflection, backlash in slides, cutter run-out, cutter deflection, and the like.

SPINDLE SPEED.
The rate of rotation of the machine spindle usually expressed in terms of RPM.

SPLIT.
Sundstrand Processing Language Internally Translated. A multi-axis (3, 4, or 5) continuous path program written by Sundstrand Machine Company for IBM computers 7090, 1620, and 650. Uses a semipidgin English language of 16-18 major word statements, and approximately 40 minor word statements. It is a specific machine oriented program requiring no post processor.

STORAGE CAPACITY.
The amount of data, usually expressed as the number of words, which can be retained in a storage or memory unit.

STORAGE MEDIUM.
Any device or recording medium into which data can be stored and held until some later time, and from which the entire original data can be obtained.

STRAIGHT CUT CONTROL SYSTEM.
A system in which the controlled cutting action occurs only along a path parallel to linear, circular, or other machine ways.

SUBROUTINE.
A portion of the total N/C program, stored in the computer's memory, and available upon call to accomplish a particular operation, usually a mathematical calculation. At its conclusion, control reverts to the master routine.

SYMPAC.
SYMbolic Program for Automatic Controls. A 3-axis continuous path program originally developed at MIT and improved upon by Univac Division, Sperry Rand Corporation for the UNIVAC Solid State computer (USS-80 and USS-90).

SYNCHRO.
Any member of a family of wound rotor magnetic induction transducers (known as selsyns, autosyns, and telesyns) that are capable of electrically transmitting and receiving angular position information.

T FUNCTION.
A code identifying a tool select command on a program tape. As with "m" and "g" codes, the "t" also appears as a lower case letter on a printout.

TAB.
A non-printing spacing action on typewriters and tape preparation devices whose code is necessary to the tab sequential format.

TAB SEQUENTIAL FORMAT.
Means of identifying a word by the number of tab characters preceding the word in the block. The first character in each word is a tab character. Words must be presented in a specific order but all characters in a word, except the tab character, may be omitted when the command represented by that word is not desired.

TAPE FEED.
A mechanism which will feed tape to be read or sensed by the machine.

TAPE PREPARATION.
The act of translating command information into punched or magnetic tape.

TEMPORARY STORAGE.
Internal storage locations reserved for intermediate and partial results.

TIME-SHARING.
The use of a device for two or more purposes during the same overall time interval, accomplished by interspersing component actions in time.

TOOL FUNCTION.
A command identifying a tool and calling for its selection either automatically or manually. The actual changing of the tool may be initiated by a separate tool change command.

TOOL OFFSET.
A correction for tool position parallel to a controlled axis.

TRACK (Formerly Channel or Level).
A path parallel to the edge of a tape along which information may be stored by presence or absence of holes or magnetized areas.

TRANSDUCER.
A device for changing one form of energy into another form, for example, from an electrical signal into mechanical motion, as in a relay.

TRANSISTOR.
An electronic device able to control electric current flow.

TRANSLATING.
Changing information from one form to another.

TRAVEL.
The distance moved between two points on a machine axis, usually given in inches.

UNITED STATES OF AMERICA STANDARDS INSTITUTE (USASI).
On August 24, 1966, the ASA was reconstituted as the United States of America Standards Institute. This is a non-profit organization which works with U.S. industry to establish national (sometimes international) standards as guides to aid the manufacturer, the user and the general public.

VARIABLE BLOCK FORMAT.
A format which allows the number of words in successive blocks to vary.

VARIABLE WORD-LENGTH.
Having the property that a machine word may have a variable number of characters. Contrasted with fixed word-length.

VECTOR.
A mathematical entity representing a directed magnitude.

VERIFY.
To check, usually automatically, one typing or recording of data against another in order to minimize human and machine errors in the punching of tape or cards.

WINDUP.
Lost motion in a mechanical system which is proportional to the force or torque applied.

WORD.
An ordered set of characters which is the normal unit in which information may be stored, transmitted, or operated upon. Example: The set of characters 10692 is a word which may give a command for a machine element to move to a point 10.692 inches from a specified zero.

WORD ADDRESS FORMAT.
Addressing each word of a block by one or more characters which identify the meaning of the word.

X-Y PLOTTER.
A device used in conjunction with a computer to plot coordinate points in the form of a graph.

ZERO OFFSET (See FLOATING ZERO).
A characteristic of a numerical machine control permitting the zero point on an axis to be shifted readily over a specified range. The control retains information on the location of the "permanent" zero.

ZERO RESET.
The ability to realign automatically each axis slide to the zero or target point by pressing a button when the slides are brought within close proximity of the target point.

ZERO-SUPPRESSION.
The elimination of non-significant zeros to the left of the integral part of a quantity before printing is begun.

ZERO SYNCHRONIZATION.
A technique which permits automatic recovery of a precise position after the machine axis has been approximately positioned by manual control.

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